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No. 2390

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OFFICE OF STRATEGIC SERVICES
Research and Analysis Branch

R & A No. 2390

SOME NOTES ON EUROPEAN EXPERIENCE IN THE BOMBING OF AIRPLANE AND BALL-BEARING PLANTS

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Description

An analysis of the results of raids on German installations of different types, and an indication of the possible implications for attack on Japanese aircraft facilities

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3 August 1944

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SUMMARY

1. Systematic air attack on the German aircraft industry succeeded in reducing output below one-third of that scheduled for single-engined fighters and below half for twin engined fighters. No similar reduction was noted in front-line strength due to the policy of conservatism adopted by the GAF shortly after the raids commenced.

2. In general, the Germans have been reluctant to instigate major repairs to those plants heavily damaged. The policy has been one of undertaking superficial and small-scale structural repairs, working those undamaged portions of a plant and dispersing the damaged portions to new locations.

3. The utilization of all available intelligence sources however, often fail to locate all new plants and the "policing" of a damaged plant is thus beset with difficulty, and it seems quite likely these problems will be magnified once strategic bombing of the Japanese aircraft industry commences.

4. The aero-engine industry may prove to be a better method of reducing Japanese production over a substantial period than would airframes. The experience in Europe in attacking both aero-engine installations and the machine-shop facilities of airframe plants suggests that widespread damage can be done to this type of installation by both HE and fire.

SOME NOTES ON EUROPEAN EXPERIENCE IN THE BOMBING OF AIRPLANE AND BALL-BEARING PLANTS

These notes briefly summarize the various aspects of target analysis, resulting damage, and the human reaction to the USAAF raids on the Axis aircraft and ball-bearing plants. The final section points a possible moral for the bombing of Japan's aircraft industry.

I. THE BOMBING OF "SYSTEMS"

In late 1942, the proposed air attack on the German aircraft industry had two objectives: (1) the quick reduction of Germany's air strength so that attacks on other, more basic targets might be made at less cost, and, (2) the long range reduction of productive facilities to insure minimized German air resistance after D-day. This problem, already difficult because of the need to keep production down over a relatively long time-span, was further complicated and attenuated because of (1) the slow initial acceleration of the program; (2) the demands imposed by other target systems; (3) the reevaluation of the German aircraft industry as the available intelligence increased; and (4) the increased resistance of German defenses.

The original recommendations for attacking the fighter-aircraft industry stated (1) that the most immediate, although short-lived results could be obtained from attack on seven final-assembly facilities and (2) that relatively long range efforts could be obtained by attacks on the plants producing those aero-engines used by single-engined fighters (SEF); (3) that propeller manufactures were considered a third choice. These recommendations were soon revised to make major airframe components - wings, fuselages, etc-- the main target as these more vulnerable phases of airframe manufacture did not lie at any significantly greater "depth" in the production process than did final assembly; and their reconstruction was known to take a considerably greater time. Aeroengines were ruled out for several reasons:

(1) A substantial percentage of both the Daimler Benz and BMW engines was used in other than single-engined fighters. This, together with the possibility of reducing "spare" engine requirements, would substantially cushion the immediate impact on fighter aircraft.

(2) Study of British experience suggested that a relatively few machine tools were subject to destruction and severe damage by HE alone. It was felt that greater damage could be done to the installations in airframe plants.

(3) The fighter-engine industry was highly concentrated around Berlin and Munich -- locations beyond the practical range of the Eighth Air Force during the first year of its existance. In addition these plants presented dispersed targets, the buildings being scattered and hidden within wooded areas.

Propellers were also eliminated as a high-priority system since insufficient knowledge existed about the importance of the various plants producing combat propellers and since it was understood that, if necessary, wooden props directly geared to drive shafts would have been used in England on de Haviland planes.

In addition to those target systems originally recommended, others were examined and in most cases rejected because lack of sufficient knowledge, the depth at which they lay, their geographic position, etc. Sodium-filled exhaust-valves were, at one time, highly recommended, but the largest producer was well hidden in Berlin proper and it was not certain how much additional output could be obtained from the remaining producers who were also difficult to locate as targets. The lag before the loss of these would be felt on engines and in turn on airframe was however the principal cause of rejection of this component. Other aero-engine components -- magnetos, fuel-injection pumps, etc. were rejected (1) because of their "depth" (2) because they were often produced by large manufacturers of electrical equipment and target identification became a problem. Until study of crashed aircraft could be made, the relative importance of the producers of instruments, radio equipment, undercarriages, etc., was largely predicated on pre-war knowledge, and even the resolution of this problem did not make them too attractive as targets. Salvage and "spare" parts sources, large scale subcontracting existing in the industry, large scale non-aircraft use (radio especially), target identification problems, etc,all combined to relegate these components to positions of minor importance.

The dominating factors, however, in making the choice of major airframe components were operational. A relatively small airforce, facing increasingly strong opposition, was at first forced to expend a considerable amount of its energy on relatively low-priority targets on the periphery of the Continent. The few blows struck at the German aircraft industry in the early phases of the campaign had to give quick relatively long-lasting dividends, and airframe components gave by far the best returns.

During the latter half of 1943, however, Allied knowledge of the framework of the German industry increased materially. The original conception of a given plant being either completely "integrated", or else engaged either in final assembly or "component" manufacture no longer was satisfactory. Study of aerial cover suggested that some plants were far too small to account for the entire output ascribed to them; other plants of the same firm -- or sub-contractors -- had to account for the remaining area. Simultaneously a considerable body of information was gathered on the organic functioning of the industry. The "Bernberg complex"[1] had been recognized for several years, but only in the fall of 1943 did it become evident that many single-engined fighter "plants" as identified by name plates were, in reality, "complexes". This knowledge made the bombing program much more precise.

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[1] Production of the Ju 88 fighter bomber was done at four principal factories: Bernberg, final assembly; Aschersleben, fuselages; Halberstat, wings; Leopoldshall, tails.

Concentration of attack on the system of "airframe components" was redefined in terms of concentration on the specific component -- at first fuselage and later the wing shops. For example the Arado firm's Warnemunde plant (making FW 190 fuselages) was apparently still knocked out as a result of an earlier raid when the Anklam plant of this company, which made wings, was attacked. At a later date the Wiener Neustadter plant at Fischamend Markt was attacked shortly after the main (fuselage) plant was damaged, and attacks on the Erla Leipzig/Abtnaundort plant closely followed the successful attacks on the main (fuselage) plant. Besides the direct loss to stocks in process, these attacks undoubtedly affected the rate of recovery at the parent plants and provided an effective method of "policing" a plant during the period when it was impossible to ascertain whether a damaged plant was being dispersed or repaired. It had also become clear that nearly complete immobilization of every plant producing this component was necessary to prevent the cross-flow of labor, sub-assemblies, detail pieces, etc., from one partially damaged fuselage (or wing) plant to another.

There were numerous attacks made on other aircraft plants which were outside the major systems concentrated upon, and several of these in fact were made on purely final-assembly facilities. These attacks were made since many paid large dividends at relatively low cost. The Focke-Wulf assembly plant at Marienburg lay nearly 800 miles from London but was essentially a "peripheral" target[1], lying immediately south of Danzig. The nearly complete destruction of this plant on October 1943 cost only two out of the attacking 100 planes, and cost the Luftwaffe at least 100 planes during the following months.

Second, attacks on these extra-systemic targets probably played important roles in attenuating the recovery rate of a firm. The attack on the Klagenfurt plant of the Wiener Neustadter in complex is an example: this plant made control surfaces and although the resulting damage could not be assessed in terms of aircraft, it added to the overall problems besetting this firm.

Third, these targets were often secondary targets, attacked when the force sent out was more than adequate for the primary objectives.

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[1] Most of the trip could be made over water.

II. THE RESULT ON OUTPUT

A. Single-Engined Fighters

German expansion plans for SEF aircraft called for an increase from less than 500 per month early in 1943 to something like 2,000 per month by the end of 1944. Output had reached the level of 900 per month by July 1943 when the first attacks were made, and during the next six months production was held to a monthly level of 600-650 by raids. The following table indicates the plants[1] attacked and presents data concerning the raids:

Date	Plant	Pre-raid output per month	Product	Estimated net loss
29 July 43	Arado Warnemunde	60	FW 190 fuselages	1 month + (70)
9 Oct. 43	Arado Anklam	60	FW 190 wings per month	±2 months
3/4 Oct.[a]	Fieseler, Kassel	40	FW 190 fuselages and final assembly	1 month +
28 July 43	Ago Oschersleben	80	FW 190	±6 weeks
9 Oct. 43	Focke-Wulf Marienburg	110	FW 190 assembly	±1 month

[a] R.A.F. Attack.

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[1] See the RE/H reports which summarize and assess the attacks on these plants.

Date	Plant	Pre-raid output per month	Product	Estimated net loss
7 Aug. 43	Messerschmitt Regensberg	225	Me 109	2 1/2 - 3 months
13 Aug 43 2 Nov 43	W.N.F. Wiener Neustadt	250 200	FW 190 fuselages and assembly	2 weeks 5 weeks
3/4 Dec 43[a]	Erla Werk V, Leipzig			(3-4 months)[b]

a R.A.F. attack
b Probably no effect on finished aircraft.

The expected net loss obtained by these attacks -- roughly 1300 aircraft -- was about a 25 percent reduction in overall output of SEF for the period 1 August - 31 December 1943. Actual output was believed kept at a considerably lower figure because of a variety of reasons:[1]

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[1] Expected output loss for any plant is obtained by estimating:
(1) the loss of stocks, finished aircraft, and work in progress and
(2) the length of time (and its resulting effect on output) to repair damage to structure or to contents for the most critically damaged production process. Thus the loss of, say, 75% of the fuselage erection facilities would be the controling factor in determing the loss of future output of a plant which had also lost 20% of its wing capacity, and 10% of the machining output. The "actual" loss is derived from subsequent name plate studies, evaluations of repair activity, etc., etc.

1. Dispersal at Wiener Neustadt ran into difficulties, and in addition, it is believed that the damage to certain installations was far heavier than it appeared on aerial cover.

2. The loss of final assembly facilities at Marienburg apparently lowered the overall output of the Focke-Wulf complex over a considerable time period. This was apparently caused by difficulty in starting other assembly plants.

3. "Systematic" effects may have played a large part. As mentioned previously, reconstruction of wing jigs for Arado may have had to await on completion of fuselage jigs for the Warnemunde plant, and these in turn may have delayed expansion of the Eastern Focke-Wulf complex at Posen, Poland, and at Soran. On the other hand poor indentification of the process damaged, sporadic raids on targets as opposed to simultaneous attack on a system, etc., might well result in an over estimation of the damage caused.

In 1944 attacks on the SEF industry became far more intense, and the attacks of 20-25 February and thereafter succeeded in reducing output to an estimated 400 or fewer new aircraft per month by the end of May, despite German effects to increase output and disperse.

The following table presents data regarding these raids:

Date	Plant	Pre-raid output per month	Product	Estimated net loss
11 Jan 44	Ago Oshcersleben	100	FW 190	
20 Feb 44	" "			6 weeks
9 Apr. 44	" "			± 7 weeks
30 May 44	" "			
16 Jan 44	WNF, Klagenfurt	± 300	Me 109 minor components	--
20 Feb 44	Erla, Leipsig	220	Me 109 fuselages and final assembly	5 months
29 May 44	" "			
22 May 44	Messerschmitt Regensburg/Ob	225	Me 109	6-7 months
24 May 44	" " "			
25 May 44	" " "			
25 May 44	Messerschmitt Regensburg/Prufening			
2 Apr. 44	Steyr Daimler Puch, Steyr.	?	Me 109 fuselage components	?
9 Apr 44	FW Poznan	110+	FW 190 components	(± 3 months)
11 Apr 44	Focke-Wulf, Cottbus			
29 May 44	" " "			
9 May 44	Arado, Warnemunde	30-40	FW 190 fuselages	(± 3 months)

(cont'd)

Date	Plant	Pre-raid Output per month	Product	Estimated net loss
11 April 44				
29 May 44	Focke-Wulf Sorau			
12 Apr 44	WNF Fischamend Markt	250+	Me 109 wings	(5 months)
16 Apr 44	IAR Brasov	10-15	Me 109	
6 May 44	" "	10-25	others	(6 months)
6 May 44	IAR Brasov			
19 May 44	Fieseler, Kassel/W			
23 May 44	WNF Wiener Neustadt			
10 May 44	"" "		Me 109 fuselages and final assembly	
29 May 44	"" "		Me 109 assembly	
29 May 44	WNF Atzgersdorf		Me 109 minor components	
30 May 44	WNF 3 dispersal plants		Me 109 fuselages	
13 May 44	Arado, Tutow		FW 190 final assembly	
29 May 44	Focke-Wulf, Pognam/Kreisling		FW 190 major components	

The intensity and generally improved results of these attacks will probably produce far more serious "systematic" results that did those earlier raids although these cannot be assessed at present.

In all, these 38 attacks (excluding those attempts unsuccessful because of weather) on 24 targets succeeded in reducing SEF output to approximately 25 percent of scheduled output, after a 10-month period. Under more ideal circumstances, this time period would have been far more concentrated thereby allowing a greater number of attacks on other more basic targets systems. As mentioned above, nearly the same results could have been accomplished with a less lavish use of forces if all the vital targets had been equally accessible. The extra-systematic attacks did destroy parts in process of manufacture and undoubtedly did attenuate the recovery rates for the principal targets.

B. Twin-Engined Fighters

The attacks on this type of aircraft were relatively well concentrated in time and were not markedly concentrated upon any one component since many of the plants - Miag, Messerschmitt, Gothaer, Duna -- as far as was known made these major components at the parent plant. In all, the 18 attacks on 10 plants listed below have succeeded in reducing output from 280 in November to an estimated 100 in April. Normally a fairly large percentage (±25) of this production is composed of fighter versions of the Ju 88, the standard twin-engined bomber, and it is apparent that unless all producers of Ju 88 were attacked, the choice of manufacturing bombers or fighters in the undamaged plants would be up to the German Air Ministry. Thus, the Siebel plant at Schkeuditz and Halle had commenced producing Ju 88 fighters after the attacks on the Junkers plants.

Date	Plant	Pre-raid output per month	Product	Estimated net loss
11 Jan 44	MIAG Brunswick/ Waggum	55	Me 110 assembly	2-4 weeks
11 Jan 44)	Junkers-Halberstadt	110	Ju 88/188 wings	Slight
20 Feb 44)	" "		"	?
22 Feb 44)	" "		"	?
11 Apr 44)	" "		"	Prob. 3-5 months
20 Feb 44	Junkers- Bernberg	110	Ju 88 assembly	1 week
11 Apr 44	" "			slight
20/22 Apr. 44	Junkers Aschersleben	110	Ju 88 Fuselages	9 weeks
24 Feb 44	Gothaer Waggum Fabrik, Gotha	75	Me 110 and gliders	2-3 months
25 Feb 44	Bachman, Furth	--	Me 110 repair & components	±2 months
25 Feb 44	Messerschmitt, Augsburg	40	Me 410 & experimental work	(± 10 weeks (tal

Date	Plant	Pre-raid output per month	Product	Estimated net loss
13 Apr 44	Messerschmitt, Augsburg	Me 410 & experimen	Me 410 & experimental work	± 10 weeks total
17 Mar 44	Heinkel, Wien/Schwechat	±15	He 219/280	
15 Mar) 23 Mar) 29 Mar) 8 Apr)	MIAG Brunswick/ Wilhelmita [1]	75	Me 110 fuselages & some wings	7 months
12 Apr 44	Duna Repolgypgar, near Budapest	20	Me 210	

In addition there have been recent attacks on the Volkswagen plant at Fallersleben and the RAF has seriously damaged parts of the Max Gerner plant. Both firms are engaged in wing production, the former making them for Ju 88 and the latter for the Me 109 and 110. Also, the Dornier plant at Oberpfaffenhofen, believed to be changing to Me 410 output was successfully attacked on three occasions.

C. Aero-Engines

Until recently attacks on German producers of aero-engines or their components have been sporadic. The Damler-Benz plants in Stuttgart and Berlin/Maienfeld, the BNW plants in Berlin and Munich/Oberweissenfeld suffered moderate damage during RAF attacks, and in addition a large producer of piston rings located in Frankfurt was very heavily damaged during a recent night raid. USAAF raids have become increasingly heavy during the past months as indicated in the following table:

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[1] There were many other "blind" attacks on Brunswick in which this plant may have been hit.

Date	Plant	Engine	Damage	Estimated Net Loss
11 Apr	Pommerische Motorenbau	Ju 211	40% structural	5-6 months
19 Apr	Henschel Mortoren Werke	DB 605	14% (¼ structural)	3 weeks
27 May	Junkers, Strasbourg/ Meinau	Ju 211	80% main machine shops	3-700 engines
27 May	Junkers, Dessau	Ju 213 (?)	Severe structural damage to machine shops	3 months output
9 June	BMW Munich/Oberwassenfeld	BMW 801	--	--
13 June	" " Allach	" "	--	--
21 June	Daimler Benz, Berlin/ Genshagen	DB 603	--	--
21 June	BMW Berlin/ Basdorf	BMW 801	--	--
21 June	Daimler Benz, Berlin/ Mariengeld	DB 603	--	--
29 June	Junkers, Magdeburg	Ju 211	--	--
29 June	Mittledeutsche Motoren Werke, Leipaig	Ju211	--	--

At present the results of these raids cannot be assessed quantitatively in terms of finished aircraft. Presumably the raids on the airframe plants have eased the BMW and DB engine position by at least permitting a higher percentage of spare engines to be sent to operating units and possibly permitting some stockpiling of engines. Whether or not a surplus of engines now exists, far greater damage would have to be done before aircraft production would be felt.

The damage in terms of a plant's estimated output has thus far been encouraging. Severe structural damage to machine shops at Strasbourg, Stettin, and Dessau have caused a net loss estimated to range between three and six months production. The damage at Stettin was particularly severe and, as is mentioned below, it is believed that over half the machine tools were either destroyed or severly damaged by this attack.

This target systen may well become increasingly important in the future. The Germans may continue to show considerable reluctance to rebuild heavily damaged airframe plants in situ and the problem of pursuing dispersed plants may be most easily solved by shifting the attack to aero-engine producers.

III. THE GERMAN REACTION

A. Industrial Repair and Dispersal

As is pointed out in RE/H 104, "Reconstruction at German Single Engine Fighter Factories", some repairs were undertaken even at those plants most heavily damaged. Damage at Marienburg, Regensburg, and Oschersleben was extensively repaired or new facilities were added, while repair activity at Kassel, Leipzig, Anklam, and Wiener Neustadt, where the damage was in general less severe than at the above three plants, were carried on at a much less intensive rate. The pattern behind this apparent random method of repair is difficult to perceive. There are a few points worth noting, however:

1. Where repairs are initiated there is seemingly a reluctance on the part of the German Air Ministry to tackle any area of structural damage greater than 20,000 sq. ft. One large important building of Erla at Leipzig received over 40,000 sq. ft. of repair, but this one exception stands out in sharp distinction to the general pattern. Superficial repairs are done to considerably greater areas. The repairs done to plants are noted in Tables 1A to 1I and are summarized in Table 2A and B on the following pages.

Table 1A. WIENER NEUSTADTER FLUGZEUGFABRIK, WIENER NEUSTADT.

DAMAGE AND REPAIRS FROM 13 AUGUST TO 1 NOVEMBER 1944

(in thousands of sq. ft.)

Function of Building	Area of Building	Total Area Damaged	Area of Structural Damage	Repairs		Remarks
				Structural[a]	Superficial[a]	
Metal shaping	215	8	8	8	—	
Boiler Ho./ office	30	2	2	2	—	
Machine ?	171	65/75?	8	0	—	some clearance
Sub-assembly	221	5	4	0	1	marginal damage
Component Erection	96	11	5	0	6	structural damage cleared
Unidentified	10	7	6	0	0	
"	3	1-	1-	1-	0	
"	6	2	2	0	0	

Table 1B. ERLA, WERK V, LEIPZIG

REPAIRS FROM 3/4 DECEMBER TO MID-DECEMBER 1943.

Function of Building	Area of Building	Total Area Damaged	Area of Structural Damage	Repairs		Remarks
				Structural[a]	Superficial[a]	
Machine shop	87	87	all)	5	0	
Sub-assembly	92	9	all)			
Offices (7)	88	26	21)			
Store	22	13	all)			

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a. Or in progress of repair.

Table 10. AGO, OSCHERSLEBEN REPAIRS FROM 28 JULY 1943 TO:

(in thousands of sq. ft.)

	11 FEBRUARY 1944					30 MAY 1944			
Function of Building	Area of Bldg.	Total Area Damage	Area of Str. Damage	Repairs Structural[a]	Repairs Superficial[a]	Total Area Damage	Area of Str. Damage	Repairs Structural[a]	Repairs Superficial[a]
Minor Component Erection	46	46	46	partially re-built					
Component Erection/Sub-assembly	49	20	2	2	18				
Raw stores susp.	97	47	12	12	35	13	all	13	0
Fin. stores	19	19	19	new bldg.	-40				
Unident.	24	24	24	0	—				
"	10	5	5	5	—				
"	5	5	5	5	—				
" (3)	41					26	26	0	—
Canteen	28					22	22	0	—
Machine & Component Erection Shop	256					65	27) 12) 45 3) 3)	0	—
Repair shop?	23					8	8	6	—
Component Erection[b]	75					2	2	0	—
Final Assembly	116					41	0	—	±40

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a. Or in progress of repair

b. Marginal damage

Table 1D. ARADO, WARNEMUNDE REPAIRS FROM 29 JULY 1943 TO 6 FEBRUARY 1944

(in thousands of sq. ft.)

Function of Building	Area of Building	Total Area Damaged	Area of Structural Damage	Repairs		Remarks
				Structural[a]	Superficial[a]	
Stores-Machine Shop and heat treatment	45	2	2	0	0	
Office	46	12	10	9.0	2.0	
Unidentified	8.4	3	3	0	—	
Paint	47	36	36	0		(cleared)
Sub-assembly/exp.?	106	11	1	1	10	
Unidentified	9	4	4	4	0	
Stores	32	8	7	0	1	
Sub-Assembly & Component Erection	69	22	3	3	0	Cleared and some reconstruction.
Unidentified (4)	30	24	24	0	—	
Heat treating offices	43	7	6	0	1	
Component Erection	91	30	6	6	24	Repairs in progress.
Boiler house	15	15	8	8	7	

Table 1E. ARADO-ANKLAM REPAIRS FROM 9 OCTOBER 1943 to MID-DECEMBER

Component Erection	83	11	5	0	3
Paint	14	1	1	0	—
Detail	26	26	26	0	—
Machine shop	42	9	8	0	1
Office	14	8	8	0	—
"	23	23		—	23
Machine shop	46	39	34	0	5
? (15)	84	32	32	0	—

---

a. Or in progress of repair.

Table 1F. FOCKE-WULF REPAIRS FROM 9 OCTOBER TO 19 FEBRUARY 1944.

(in thousands of sq. ft.)

Function of Building		Area of Building	Total Area Damaged	Area of Structural Damage	Repairs		Remarks
					Structural[a]	Superficial[a]	
Assembly		80	34	0	—	34	
"		65	65	65	31	(new bldg.)	
"		69	69	39	0	0	
Hangar		47	47	16	5	31	
"		33	26	16	0	10	
"		66	66	22	16	9	
Store		33	33	33	0	—	
Canteen		17	17	17	3	—	
Power house		16	13	13	13	—	
Unidentified	(3)	9	7	7	0	—	
"	(1)	11	11	11	0	—	
"	(7)	16	3	2	0	—	
"	(3)	6	2	2	2	—	
"	(1)	11	11	11	0	—	
"	(1)	1	1	1	0	—	
"	1	3	2	2	0	—	
"		27	3	3	3	—	
"	(8)	25	24	24	0	—	
Gatehouse		16	16	16	0	—	

---

a. Or in progress of repair.

Table 10. FIESELER, KASSEL/BETTENBAUSEN REPAIRS FROM 30 JULY TO:

(in thousands of sq.ft.)

	3/4 OCTOBER 1943					MID DECEMBER 1943			
Function of Building	Area of Bldg.	Total Area Damaged	Area of Struc. Damage	Repairs Structural[a]	Repairs Superficial	Total Area Damage 3/4 Oct	Area of Str. Damage	Repairs Str.	Repairs Sur.[a]
Store?	36	18	18	0	—				
Component Erection	86	4	4	4	0	11	0	21	5
Machine Shop	24	19	5	1	14	20	all		
Boiler house	5	2	2	0	—				
Machine Shop	72					1	0		
" "	30					24	24		
Sub-assembly/ Component Erection	44					2	0		
Fi-156Component Erection	74					29	28		
Canteen	12					12	12		
Unidentified									
"	7					3	0		
"	6					6	6		
"	2					1	0		
"	4					4	4		
Experiment	8					8	0		
"	9					9	9		
Guard Ho.	18					10	10		

---

a. Or in progress of repair.

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Table 1H. ERLA LEIPZIG/HERTERBLICK REPAIRS FROM 20 FEBRUARY TO 29 MAY

(in thousands of sq. ft.)

Function of Building	Area of Building	Total Area Damaged	Area of Structural Damage	Repairs Structural[a]	Repairs Superficial[a]	Remarks
Final Assembly	59	25	14	14	11	
Final Assembly	50	17	5	5	12	
Component Erection	80	55	53	± 45	0?	
Press and Machine Shop	16	16	16	16	—	
Stores, press & Machine shop	89	71	71	± 1	—	
Sub-Assembly	60	47	42	3	—	
Garage & office	7	7	7	4	—	
Office	18	18	6	0	12	

---

a. Or in progress of repair.

Table 11. MESSERSCHMITT, REGENSBURG, REPAIRS FROM 17 AUGUST 1943 TO 31 JANUARY 1944.

(in thousands of sq. ft.)

Function of Building	Area of Building	Total Area Damaged	Area of Structural Damage	Repairs Structural[a]	Repairs Superficial[a]	Remarks
Workers huts	129	40	40	0	—	
Office and canteen	26	16	16	8	—	
Office	18	7	5	5	1	
Stores	44	6	0	—	0	
Bicycle shed	17	2	2	0	—	
Garage	6	1	1	0	—	
Unidentified[b].	19	8	7	0	1	
"	19	2	0	—	1	
"	48	8	5	1	3	
"	11	10	10	0	—	
"	62	46	21	0	9	(+16 cleared)
"	20	7	7	0	—	
"	26	6	6	0	—	
"	19	3	3	2	—	
"	30	16	16	0	—	
"	20	9	9	0	—	
"	54	18	15	0	3	
"	10	8	8	0	—	
Machine shop(press)	59	35	5	0	3	
" " "	58	21	8	0	13	
Machine shop	65	25	11	11	14	
Metal stamping & detail	47	45	45	0	—	
Metal stamping & detail	42	24	22	0	2	
Sub-assembly	59	23	2	1	21	
Sub-assembly & Component Erection	86	49	22	0	23	
Component Erection	103	16	3	3	13	
Component Erection (?)	48	2	2	0	—	
Stores/armament shed ?	58	36	9	9	27	
Gun test	30	4	3	3	1	

---

a. Or in progress of repair.

b. Generally more than one building.

Table 2A. STRUCTURAL REPAIRS

(in thousands of sq. ft.)

Area of Damage	0 - 10	11 - 20	21 - 30	31 - 40	41 - 50	Over 50
Area of repairs to:						
Machine shop						
1					0[a]	
2	0[b]					
3						0
4	1	0				
5	0					
6			0			
7						0
8	0					
9	0					
10		11				
11		16				
12	0					
13				0		
14					0 (new bldg)	
Component Erection/Sub-Assembly						
1					0 (new bldg)	
2		2				
3	0					
4	0[b]					
5	0[b]					
6	4					
7	0?					
8	3					
9	1					
10			0			
11	1					
12	3					
13	6					
14						£45
15					3	
16	0					
17			0			
Final Assembly						
1	0					
2						0 (New Hangar)
3		14				
4	5					

a/ 4 separate areas - 27 - 3,000 sq.ft.   b/ W.N.F. dispersed

Structural Repairs

	0 - 10	11 - 20	21 - 30	31 - 40	41 - 50	Over 50
Hangars						
1		54				
2	0					
3			16			
Stores						
1				0		
2		0?				
3		(12 (13				
4		40 (new bldg)				
5		0				
6	0					
7	0					
8	0					
Msc.						
Repair	6					
Gun test	3					
Offices 1		8				
" 2	9					
"	2					
"		0				
"	7					
"	0					
"			0			
Canteen		0				
"		3				
Garage	3					
Boiler house	8					
?	5					
?	5					
?	0					
?	0					

---

c/ Marginal

Table 2B. Superficial Repairs

(in thousands of sq. ft.)

Area of Damage	0 - 10	11 - 20	21 - 30	31 - 40	41 - 50	Over 50
Area of repairs to:						
Machine shops						
1		0				
2		14				
3						0[a]
4				3		
5		13				
6		14				
Component Erection/Sub-Assembly						
1			21			
2			23			
3		13				
4	1					
5		0[b]				
5a			24[c]			
6	0					
7		10				
8		18				
9		0				
Final Assembly						
1				34		
2			0			
3		11				
4		12				
5					40	
Hangars						
1				31		
2	10					
3						9[d]
Stores						
1	0					
2			27			
4				35		
Office	2	12				
Heat treatment	1					
Boiler house	7					

a/ W.N.F. - glass needed

b/ Arado - eventual clearance

c/ Repairs in progress

d/ Remainder cleared

2. The sample is quite small but shows no order of repair priority. Thus at Ago, buildings identified as incoming stores and possibly a repair shop received repair following the attack of 11 February 1944 while the main machine shop which had received superficial and structural damage[1] was not touched.

3. The geographic vulnerability of a plant largely determined the quantity and rate of repair or its dispersal. At Wiener Neustadt, partial dispersal was commenced following the first raid and as a result even so simple a problem as replacing roofing glass was not undertaken for certain buildings. Repairs and clearance at Arado, Warnemunde, were done at a very slow rate. The exposed (peripheral) location influenced the choice either to move undamaged equipment to other Arado branches or to the new Focke-Wulf plants in Sorav. Repairs were made or started at Erla at Leipzig and Messerschmitt at Regensburg (see also below) both plants being in comparatively "safe" areas.

4. There is a tendency to maintain work in the undamaged portions of a factory -- i.e., dispersal is mainly made to the damaged facilities.

5. As far as is known at present, dispersal (when made) has been made to nearby, existing facilities. The Wiener Neustadter Werk II plant was scattered to four nearby textile and carpet factories and possibly to two other branches of the firm; Messerschmitt moved into its Regensburg/Obertraubling plant and rebuilt and added to the damaged plant at Regensburg/Prufening.

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[1] As noted on Table 10, superficial damage amounted to 20,000 sq.ft. while structural damage ranged between 3,000 and 27,000 sq.ft., totaling 45,000 sq.ft.

6. These dispersed locations will, of course, be more difficult to knock out than were the original sites. Not all of them will be known since once a plant has moved, the very knowledge of its new location will (for everything other than final assembly) be dependent on ground intelligence or P/W information which will only be obtained at a much later period. Components are rarely photographed at the plant at which they are built; they are usually moved quickly to the next higher stage of fabrication. In addition, the small site area and the possibility that duplicative functions may be set up[1] all tend to reduce the value of a plant once moved.

---

[1] An example of extreme dispersal is shown in the following table of a British fighter complex, comprising 55 separate plants, itself nearly 50 per cent dependent on subcontractors, not listed below:

Distribution of Floor Area by Function.

Function	No. of plants in complex performing function.	Floor areas of individual plants (in thousands of sq.ft.)
Post assembly	1	14
Final assembly	3	79, 41, 18
Wing assembly in jigs	5	16, 8, 6, 5, 4
Wing assembly out of jigs	6	11, 10, 9, 7, 4, 3
Fuse. assembly in jigs	4	6, 4, 3, 3
Fuse. assembly out of jigs	7	17, 11, 10, 10, 10, 7, 6
Control surfaces	1	2
Sub-assembly	7	13, 12, 11, 9, 9, 6, 1
Detail fitting	14	17, 12, 8, 6, 6, 6, 6, 5, 4, 4, 4, 2, 1, 1
Machine shop	4	20, 19, 7, 7
Press shop	3	18, 3, 1

B. The Effects on Strength

The results of these attacks on the strength of the Luftwaffe were twofold: (1) They produced a marked leveling off of SEF strength which had increased from around 1,200 planes at the beginning of 1943 to around 1,700 at the time the attacks commenced; (2) Moreover, a decline in strength was prevented only by a marked policy of plane conservation. The GAF scale of effort, measured in sorties, was high during 1944, but the qualitative intensity of opposition was low and probably declined over that of the latter part of 1943. Stragglers, unescorted formation, etc., bore the brunt of attack. A sharp distinction among three types of attacks -- shallow, deep "blind", and deep visual -- is revealed by the percentage of US bombers lost and the number of German fighters claimed, both figures being higher for deep visual attacks. This policy is continuing at present; the Luftwaffe is still reluctant (or unable) to engage in strength either on the Normandy beach-head or against most strategic strikes, and as a result fighter strength has only suffered a slight decline since the start of the Normandy campaign.

Twin-engined-fighter strength reached its all-time peak in January (the month attacks commenced on this system) and have since shown a slight overall decline. These aircraft have also shown a far less aggressive policy since the beginning of 1944.

Chart No. 1 on the following page shows front line strength and reserves of these two aircraft types during the past year.

SECRET

PRELIMINARY DRAFT

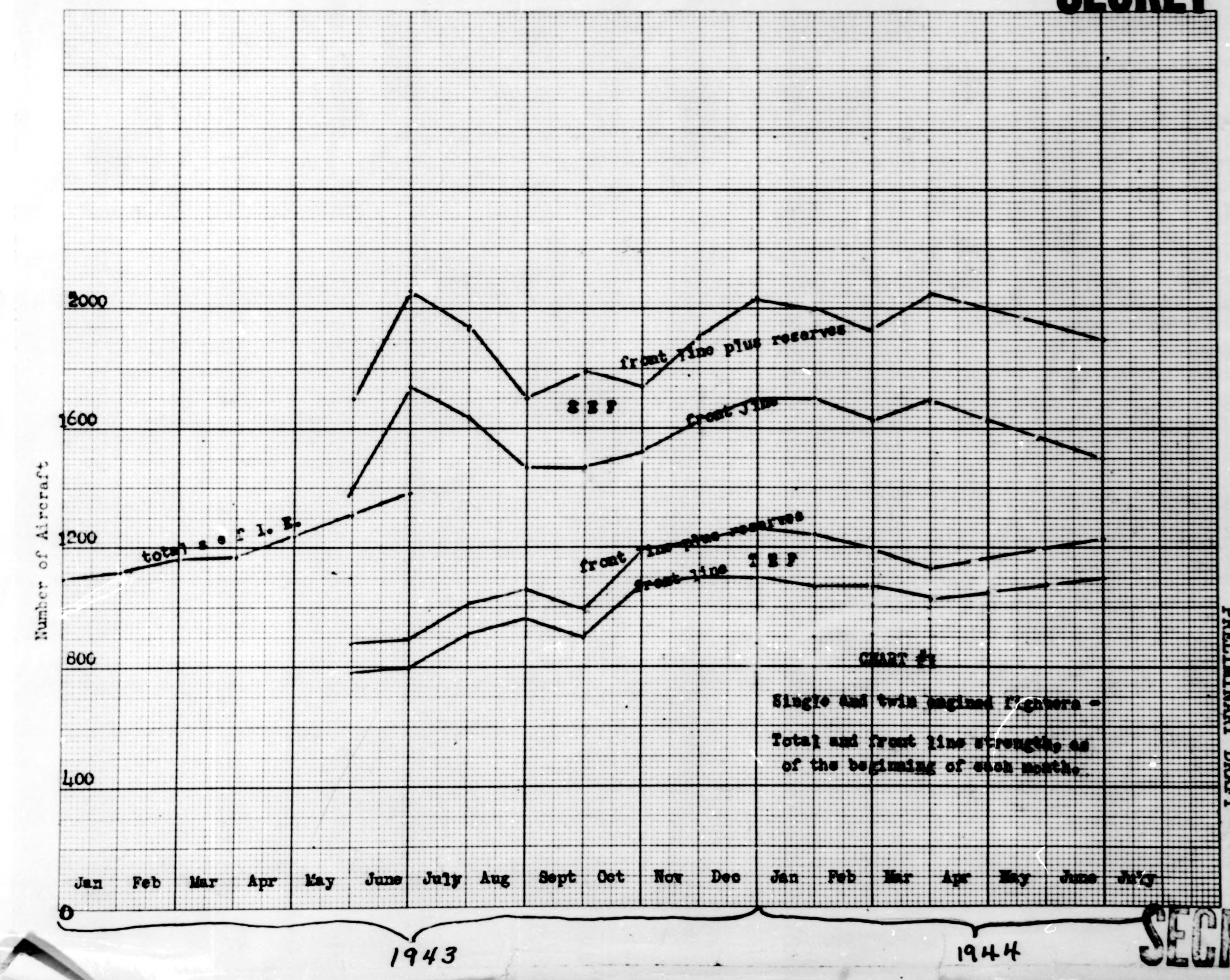

CHART #1

Single and twin engined fighters -

Total and front line strength, as of the beginning of each month.

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IV. PHYSICAL VULNERABILITY AND RESULTING DAMAGE

A. Airframes

1. Vulnerability of Content and Structure. The contents and processes of an airframe plant are primarily targets for HE rather than IB attack. Because of the heavier equipment involved, the machine and press shops are less vulnerable than are the component erection/sub-assembly processes, and the relatively simple equipment needed for final assembly make this fabrication stage the least attractive of the three.

The areas of combustible material are relatively small and are unequally distributed throughout a plant. These consist of the paint and dope shops, offices, and stores, and they are often housed in separate buildings in German plants. In general, the contents of machine and press shops are less combustible than are component erection and final assembly, excepting those highly combustible areas mentioned previously.

These degrees of content combustibility are almost altogether controlled by the nature of the structure. A combustible structure (say, a roof of wood planking) will carry a fire throughout a building and will permit those isolated portions of combustible material to ignite. Table 3 on the following page shows that a high percentage of damage, both relative and total, have been done by fire or fire and HE to the relatively less combustible processes in German machine and

TABLE 3. FIRE OR FIRE AND HE DAMAGE TO PROCESSES

Plant	Process	Estimated structural combustibility	IB as percent of total	Structural damage (1) Percent of total function	of which (2) HE (%)	of which (3) Fire or fire & HE (%)	(3) as percent of (1)	Remarks
Erda, Leipzig/H.	Machine shop	Combustible	25	86	70	16	19	
	Component erection/ sub-assembly			39	10	29	74	
Me - Regensburg/P	Machine shop	Non-combustible, 1st raid	19	36.5	7	29.5	79	Function included Leichmetall with high content combustibility
		2nd raid	15	37	37	0	0	
	Component erection/ sub-assembly	Possibly combustible in part 1st raid	19	4	4	0	0	
		2nd raid	15	45	24	21	46	Combined fire and HE in wood trussed buildings
Wm. Neust'der, Wm. Neustadt	Machine shop	Non-combustible, 1st raid	1	4	4	0	0	
		2nd raid	0	5	5	0	0	
	Component erection/ sub-assembly	Non-combustible, 1st raid	1	2	1.3	.7	33	
		2nd raid	0	5	5	0	0	
Fieseler, Kassel/B	Machine shop	Non-combustible	22	38	0	38	100	RAF area raid
AGO, Oschersleben	Machine shop[a]	Non-combustible, 1st raid	34	0	0	0	0	
		2nd raid	52	17	0	17	100	Note high percent of IB
		3rd raid	46	15	0	15	100	
	Component erection/ sub-assembly	Non-combustible, 1st raid	34	26	26	0	0	
		2nd raid	52	1	1	0	0	
		3rd raid	46	0	0	0	0	
Arado, Warnemunde	Component erection/ sub-assembly	Non-combustible (?)	19	3	3	0	0	

---

a. Includes considerable component erection/sub-assembly.

(continued)

TABLE 3. FIRE OR FIRE AND HE DAMAGE TO PROCESSES (continued)

Plant	Process	Estimated structural combustibility	IB as percent of total	(1) Percent of total function	(2) HE (%)	(3) Fire or fire & HE (%)	(3) as percent of (1)	Remarks
unkers, Aschersleben	Machine shop) Component erection/) sub-assembly)	Non-combustible	16 16	3 ?	3 ?	0 ?	0 ?	
unkers, Bemberg	Final assembly	Possibly combustible	.15	2	2	0	0	
ocke Wulf, Poznan	Machine shop) Component erection/) sub-assembly)	Combustible	33	(98	0	98	100	
				(9	2	7	73	
. Neustadter ischamend	Machine shop) Component erection/) sub-assembly)	Non-combustible	0	(32	32	0	0	
				(45	31	13	29	Combined fire and HE with no IB dropped
AG, runswick/W[a]	Machine shop	Both combustible and non-combustible)	31[a]	(2	2	0	0	
	Component erection/ sub-assembly	Combustible)		(93	5	88	96	
AG, runswick/W	Final assembly	Possibly combustible	0	17	12	5	33	Combined fire and HE with no IB dropped

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[a] Raid of 8 April only.

press shops. This table includes only those German plants where fair or good identification of process are known. It will be noted that there is excellent correlation between the predicted "combustible" structures that housed these functions and the damage done by fire or fire and HE. Of the 9 machine and press shops listed, two were believed to have combustible structures and the damage involving fire was 19 percent and 100 percent of the total damage done. The other seven were partially or altogether considered non-combustible and with two exceptions showed little or no inclination to burn. The two exceptions were Messerschmitt at Regensburg and Fieseler at Kassel. Damage to the former included the Leichmetallwerke which, presumably, had highly inflammable contents, and the gutting of two Fieseler machine shops may well have been due to a chance saturation of IB during the RAF night attack of 3/4 October 1943.

Table 3 also shows that fire or fire and HE played an important role in damaging the component-erection and sub-assembly phases of airframe manufacture. Of the eleven places listed, four were believed to be housed in combustible structures, five were considered non-combustible, and one was probably partially combustible. Fire damage to the first four ranged from 50 to 100 percent of the total damage done and generally involved large areas; it was ranged between 0 and 33 percent for most of those in the second category, although in one instance it accounted for the entire damage. However, the most damage done to non-combustible structures was only 17 percent of the total area. In the doubtful case -- Regensburg -- the damage by fire was 0 and 47 percent of the total damage for the two raids, the latter figure being 21 percent of the entire area.

Occasionally, some damage involving fire has been done by HE alone. In general, however, this has been confined to the more combustible areas (for example, the stores of MIAG at Brunswick/Waggum) but there was at least one occasion where considerable damage (13,000 sq. ft.) was done to a component erection itself. This incident occurred at the Wiener Neustadter Flugzengwerke wing plant at Fischamend Markt. In general the IB dropped usually ranged between 15 percent and 30 percent of the total dropped; occasionally it went as low as 9 percent and on some of the raids on AGO at Oschersleben and Messerschmitt at Augsburg it ran as high as 52 and 75 percent. There seems to have been little or no correlation between the size of the site area or the "built-upness" of a plant or the estimated combustibility of a site with either the total tonnage dropped or the ratio of HE to IB. These relationships are summarized in Table 4, on the following page.

2. The Estimated Production Loss. The component-erection and/or sub-assembly phase of airframe construction are not only

TABLE 4. GERMAN AIRCRAFT SITE AREAS AND TONNAGES DROPPED

Date	Plant	(1) Site area (in 1000 sq. ft.)	(2) Bldg. area	(2) as percent of (1)	Tonnage dropped		Percent IB of total dropped	Tons HE per 1000 sq. ft.	Tons IB per 1000 sq. ft.	Tons HE per acre	Tons IB per acre
					HE	IB					
11 Jan. 1944	MIAG, Brunswick/Waggum	1,900	344	18	90.5	none	0	.047	-	2.04	-
17 Aug. 1943	Me Regensburg/Prufening	6,510	1,525	23	242.7	56	19	.037	.086	1.60	3.74
22 Feb. 1944	Me Regensburg/Obertraubling	3,271	656	20	331	66	17	.101	.02	4.39	.087
25 Feb. 1944	Me Regensburg/Obertraubling	3,271	656	20	387	none	0	.118	-	5.13	-
25 Feb. 1944	Me Regensburg/ Prüfening	6,510	1,608	25	436	80	16	.066	.012	2.87	.52
30 July 1943	Fieseler, Kassel/Walden	1,320	460	35	65	32.5	33	.049	.024	2.13	1.04
30 July 1943	Fieseler, Kassel/Bettenhausen	1,425	569	40	170	47.7	22	.119	.033	5.18	1.43
19 Apr. 1944	Fieseler, Kassel/Walden	1,320	460	35	166	79	32	.125	.059	5.43	2.56
20 Feb. 1944	ERLA, Leipzig/Heiterblick	3,000	775	26	115	39	25	.038	.013	1.65	.56
20 Feb. 1944	ERLA, Leipzig/Mockau	878	242	27	86	34	28	.097	.037	4.21	1.61
29 July 1943	Arado, Warnemunde	2,613	760	29	105	24	19	.040	.009	1.74	.39
9 Apr. 1944	Arado, Warnemunde	2,613	840	32	139	53	28	.050	.02	2.17	.87
9 Oct. 1943	Arado, Anklam	1,437	395	27	159	26	13	.110	.018	4.78	.78
11 Jan. 1944	AGO, Oschersleben	3,000	1,1[illegible]	34	233	79	25	.077	.026	3.34	1.13
20 Feb. 1944	AGO, Oschersleben	3,000	991	33	75	39	34	.025	.013	1.08	.56
11 Apr. 1944	AGO, Oschersleben	3,000	1,015	34	246	114	32	.082	.038	3.56	1.65

TABLE 4. GERMAN AIRCRAFT SITE AREAS AND TONNAGES DROPPED (continued)

Date	Plant	(1) Site area (in 1000 sq. ft.)	(2) Bldg. area	(2) as percent of (1)	Tonnage dropped HE	Tonnage dropped IB	Percent IB of total dropped	Tons HE per 1000 sq. ft.	Tons IB per 1000 sq. ft.	Tons HE per acre	Tons IB per acre
24 Feb. 1944	Gothaer, Gotha	5,700	1,927	34	350	74	17	.061	.012	2.65	.52
15 Mar. 1944	MIAG, Luther Werke	1,500	498	33				.120	.376	5.22	16.35
23 Mar. 1944	MIAG, Brunswick/Wilhelmitor							.270	.047	11.74	2.04
29 Mar. 1944	MIAG							.062	.200	2.69	8.7
8 Apr. 1944	MIAG				239	75	24	.159	.050	6.91	2.17
20 Feb. 1944	Junkers, Bernburg	3,600	559	15	83	2.1	20	.023	.0005	1.0	.021
22 Feb. 1944	Junkers, Bernburg	3,600	559	15	113	none	0	.031	-	1.34	-
22 Feb. 1944	Junkers, Aschersleben	5,540	803	14	64.5	12.5	16	.011	.002	.47	.087
25 Feb. 1944	Bachmann, Furth	1,235	495	40	360	60	14	.291	.048	12.65	2.08
12 Apr. 1944	WNF, Fischamend	1,960	490	25	116	None	0	.059	-	2.56	-
7 Apr. 1944	Focke Wulf, Poznan	871	493	57	50	25	33	.057	.028	2.47	1.21
20 Feb. 1944	ATAG, Leipzig/Mockan	1,855	400	21	102	none	0	.054	-	2.34	-

TABLE 4. GERMAN AIRCRAFT SITE AREAS AND TONNAGES DROPPED (continued)

Date	Plant	(1) Site area (in 1000 sq. ft.)	(2) Bldg. area (in 1000 sq. ft.)	(2) as percent of (1)	Tonnage dropped HE	Tonnage dropped IB	Percent IB of total dropped	Tons HE per 1000 sq. ft.	Tons IB per 1000 sq. ft.	Tons HE per acre	Tons IB per acre
13 Aug. 1943	WNF, Wiener Neustadt	5,227	1,878	36	110	12	10	.021	.002	.91	.087
2 Nov. 1943	WNF, Wiener Neustadt	5,227	1,855	36	327	none	0	.062	-	2.69	-
23 Apr. 1944	WNF, Wiener Neustadt	5,227	1,833	36	513	none	0	.098	-	4.2	-
9 Oct. 1943	FW, Marienburg	4,138	639	15	149	68	31	.036	.016	1.56	.69
25 Feb. 1944	Me, Augsburg	8,158	1,989	29	370	133	26	.022	.016	.95	.69
13 Apr. 1944	Me, Augsburg	8,158	2,016	29	37	118	76	.004	.014	.17	.60
11 Jan. 1944	Junkers, Hallierstadt	6,969	?	?	7.8	4.7	37	.001	.0006	.026	.043
11 Apr. 1944	Junkers, Barnburg				139	127	48				
16 Jan. 1944	Wn. Neustadter, Klagenfurt	217	108	50	201	none	0	.926	none	40.2	none
11 Apr. 1944	FW, Cottbus				39.5	none	0				
11 Apr. 1944	FW, Soran	9,900	?	?	79.5	305	80	.007	.030	.30	1.3

more vulnerable to both IB and HE attack than are the other processes, but are in addition, the most difficult to replace; widespread destruction of sub-assembly and erection jigs are liable to take as long as six months to replace, while the machine tools used in airframe plants are not specialized and the work can, to a very large degree, be subcontracted while repairs and replacements are being made. Final-assembly facilities are replaced or repaired with the greatest speed.

Charts 2, 3, and 4 on the following pages show the estimated net loss resulting from attacks on machine and press facilities, component erection and sub-assembly and final assembly respectively. These amplify the premises stated above. Structural damage to machining facilities has run over 85 percent in three instances, (Erla Leipzig, Heiterblich, 86 percent; Focke-Wulf, Poznan, 98 percent; Erla, Leipzig, Werk V, 100 percent) the net estimated loss from these attacks is estimated at six months for Focke-Wulf, three to four months for Erla Werk V, and four to six months for Erla-Heiterblick -- i.e., nearly complete loss of a machine shop is believed to result in a net loss of about four months output.

The estimated damage to sub-assembly and component erection facilities (Chart 3) suggests that a production loss equal to that sustained by machine shops can be attained by half of the structural damage, and that when this damage exceeds 50

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PRELIMINARY DRAFT

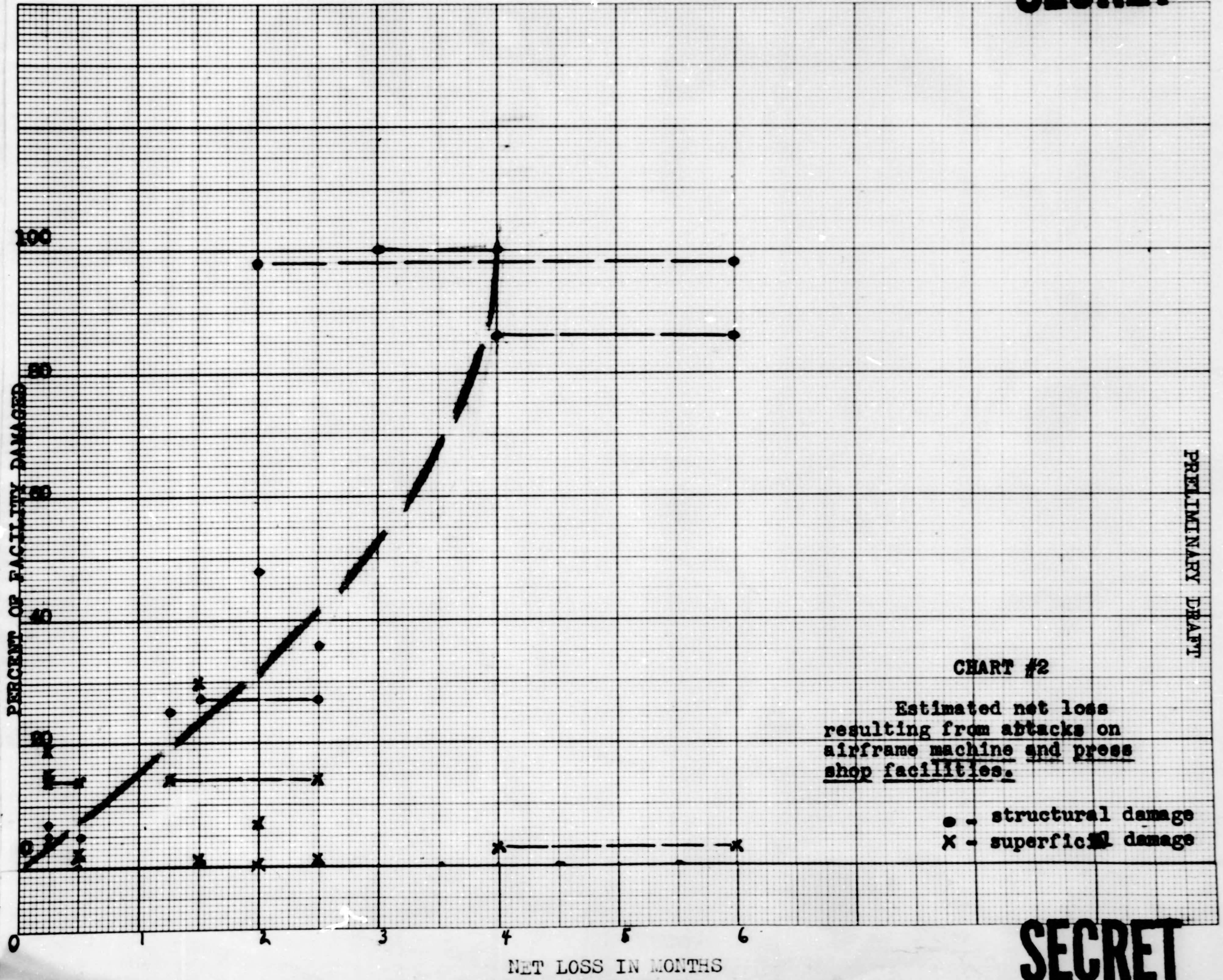

CHART #2

Estimated net loss resulting from attacks on airframe machine and press shop facilities.

● - structural damage
X - superficial damage

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PRELIMINARY DRAFT

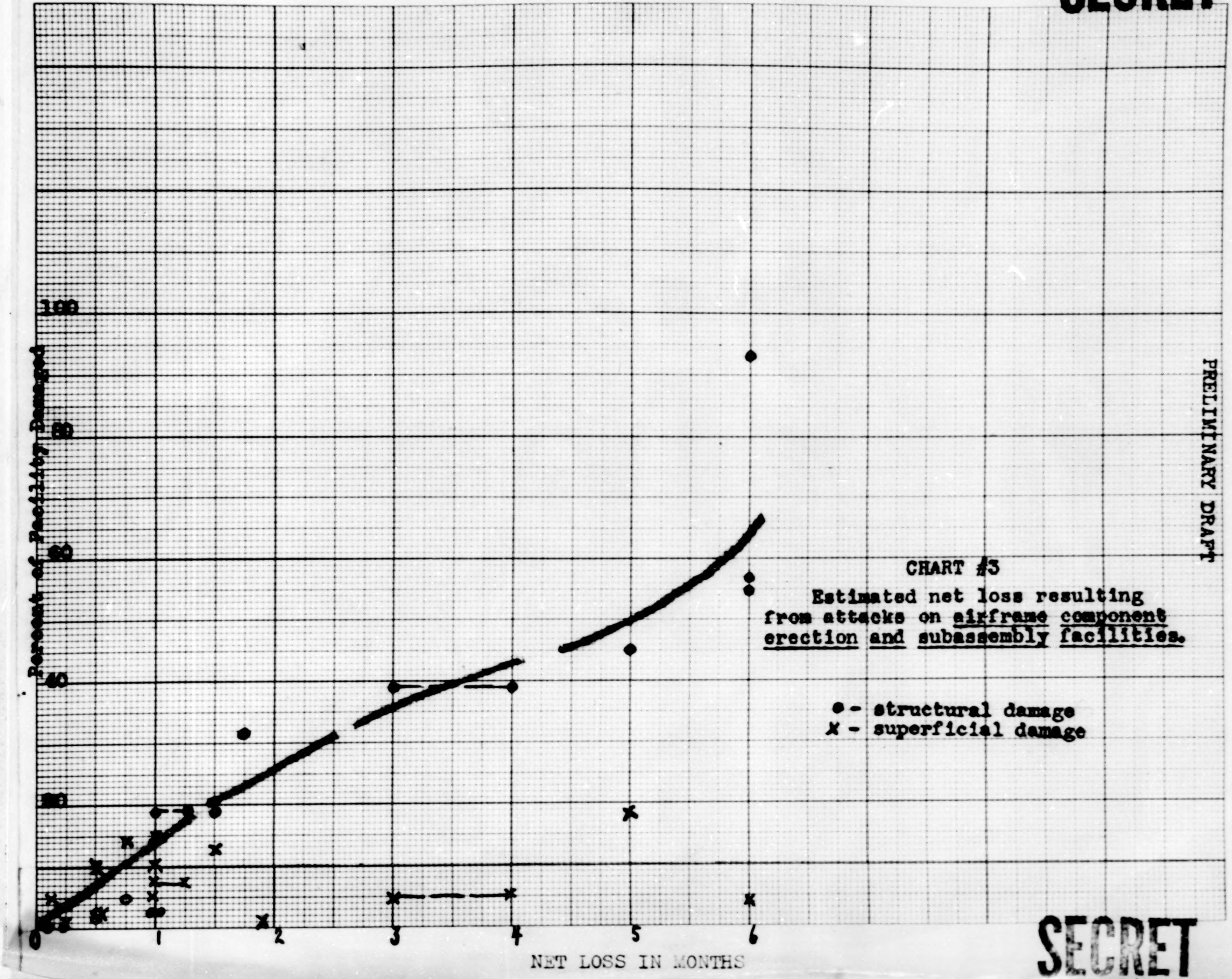

CHART #3

Estimated net loss resulting from attacks on airframe component erection and subassembly facilities.

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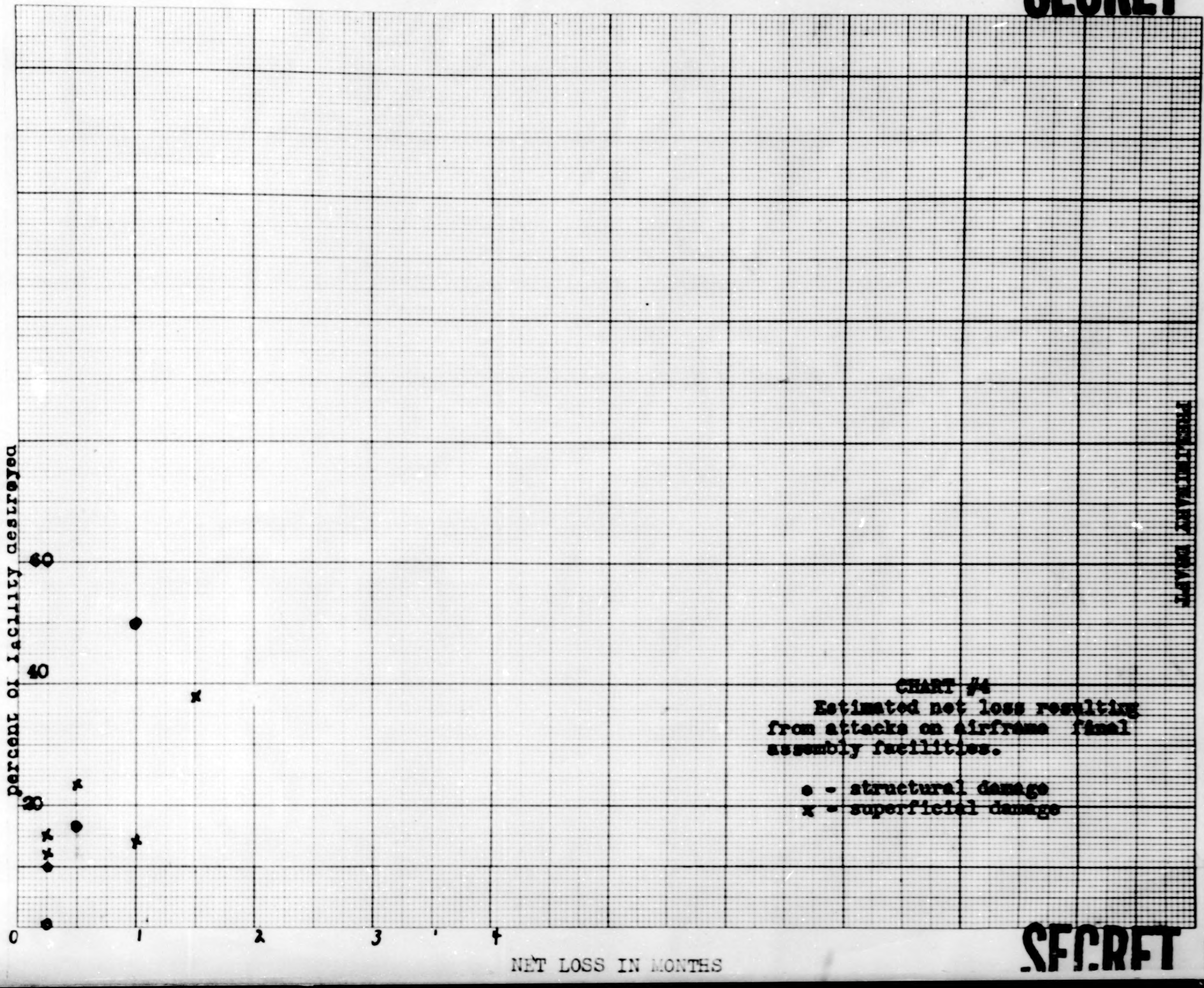
PRELIMINARY DRAFT

CHART #4
Estimated net loss resulting from attacks on airframe final assembly facilities.

● - structural damage
x - superficial damage

SECRET

percent of the total, the loss is at least six months net output. The results of attack on final assembly plants are plotted in Chart 4, and these suggest that even moderately heavy damage will only result in one month to six weeks' net loss. This loss may be spread out over a considerably greater time period than is the loss to the two other stages of fabrication. The heavy damage done to Marienburg was believed to have resulted in one month net loss spread over six months time.

There is little or no empiric evidence to substantiate these estimates. The reconstruction at Regensburg, where 36 percent of the machine and press shops (including the Leichmetallbau, engaged in basic metal work) were structurally damaged suggests that the original estimated loss of two and a half months output should have been placed at three months.

B. Aero-Engines

The attacks of May and June on the engine plants listed on page 15 have occurred too recently to permit an appraisal of damage done to processes or, as pointed out previously, to gauge the effect on aircraft output. In several instances the damage has been exceptionally severe, as suggested in the following sample:

1. Pommerische Motorenbau, Stettin: Fully framed single-story structures with precast concrete roofs. Site area 3,900,000 sq. ft.; 20 percent built up. Estimated minimum

output 200 new and repaired Ju 211 per month.[1] Attacked 11 April 1944 with 135 tons of HE (530 X 500 lb. HE) and 65.7 tons of IB (1,314 X 100 lb. IB) dropped from 14,000 - 17,000 feet. There was a high concentration of hits in the target area resulting in damage to 40 percent of the entire factory and 55 percent of the machine shop area. Loss estimated at five to six months; at least half machine tools severely damaged or destroyed.[2] Over 80 percent of the damage to productive buildings caused by fire and HE combined.

2. Junkers-Strasbourg/Meinau: Fully framed structures with wood-planked roofs. Plant area ± 2,800,000 sq. ft.; ±25 percent built up. Repairs and possibly some new Ju 211 output. Attacked 27 May 1944 with 130 tons of GP bombs. A high concentration of bursts in the target area resulted in the machine shop being 60 percent destroyed by HE and fire. Minor damage to other buildings. Loss estimated at a minimum of 300 and a maximum of 700 engines.

3. Hobus Werke, Woippy: Typical non-combustible fully

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[1] Reported sabotage may have kept the output down to this level; capacity may have been about 350 - 400 per month.

[2] Recent ground intelligence suggested that 75 percent of the machinery was in this category; this may be over-exaggerated, however.

framed structure. Attacked 27 May with 134 tons BG, 38.5 tons IB. Fairly severe damage to two workshops.

4. Junkers Flugzeug u. Motorenwerke, Dessau: Research in experimental engines. Believed to be typical non-combustible structures. Large area, about 40 percent built up, including airframe plant, gas heater works, head offices, etc. Attacked 30 May with 145 tons of 500 lb. GP and 45 tons of 100 lb. IB. Extremely heavy damage to two large machine shops which are almost completely gutted and collapsed. Loss estimated at three months output.

5. Henschel Flugmotoren, Kassel: Believed typical non-combustible structure. Attacked 19 April with 42 tons of 500 GP and 73 tons of 100 lb. IB. One store burned; one machine shop suffered 90 percent superficial fire and HE damage.

Preliminary assessments of the other six raids are not available as yet. However, even the small sample given above strongly suggests that:

(1) extensive areas of damage can be done to machine shops

(2) fire and HE combined play a very important role in producing this damage, and the resulting machine tool losses are far higher than was British experience, which dealt purely with HE[1]

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[1] A recent RE/N paper (#301) suggests that a 500kg S.C. bomb, exploding just below the roof, would destroy or severely damage machines over 3-4,000 sq. ft. This would amount to 15-20 machines at 200 sq. ft. (total machine shop area) per machine.

(3) The fairly high percentage of IB to total dropped (35 percent at Stettin, for example) have resulted in this large HE and fire damage despite the general non-combustibility of the structures. Fires were started at Strasbourg in a combustible building even though no IB was dropped.

(4) Greater net loss per percent of shop destroyed will result from attack on engine as opposed to airframe machine shops. The more specialized work done in engine plants precludes the possibility of subcontracting work at a moment's notice. Thus, destruction of 55 percent of this facility at Pommerische Motorenbau resulted in an estimated six months loss. Generally, it takes nearly complete destruction of an airframe machine shop to obtain a loss of even four months. The small sample obtained thus far suggests that, when structural damage to productive facilities is 50 percent or less, the production loss for an engine plant is about equal to that of component-erection and/or sub-assembly -- i.e., both result in a net loss of about six months output. Heavier damage to the airframe facilities do not, however, cause a much greater loss, and it seems probable that this effect will not be noticed with engine plants suffering over 50 percent damage -- a plant with 75 percent of its machining capacity damaged may be out for eight or nine months.

V. THE ROLE OF INTELLIGENCE

A. Aerial Cover

Aerial cover has been so basic to all target appraisal, to the operations themselves, and to damage assessment that little need be said at this point about its role. Floorspace interepretations based on photographic cover are discussed below.

B. Ground Intelligence

Next in importance to aerial cover have been the reports issuing from various underground sources -- Polish Intelligence, Free French, etc. These reports contained many weaknesses -- reports of bomb damage were almost always exaggerated; little trust could be placed in the number of employees or the physical size or output of a plant; even the actual activity of a plant was often erroneously given, (repair work confused with final assembly, engine work called aircraft production, etc.); however, they were nearly infallible in "spotting" the physical existence of a plant. Thus, ground intelligence gave ample warning of the dispersal of the Focke-Wulf Bremen complex to Poland; it gave the location of five of the seven Wiener Neustadter plants and the four textile factories taken over by this firm for dispersal were reported after two to three months lag. A report written in London last August listed some 25 places in Southern Europe reported by ground intelligence to be engaged in aircraft production. None of these had been photographed at that time, but subsequent cover proved the existence of 22 of these plants. Of the three which could not be tied in to the aerial cover, one was located but was subsequently believed to be engaged in other activity, a second was believed quite small and was, moreover, located in an urban area, the third was not located.

Experience has shown that (1) if a plant is mentioned three times within a year, its existence can usually be taken as being proved; (2) its actual function must, however, be determined from other corroborating sources.

C. P/W and Refugee Interrogations

Reports from these two sources have proved invaluable in giving precise information about a plant's activity, the identification of its principal buildings, and, quite often, production estimates. For example, confirmation of the above mentioned move of Focke-Wulf from Bremen to Poland was confirmed by P/W interrogation many months before aerial cover was obtained; building identifications were received from another P/W on a newly erected ball-bearing works in Austria (previously mentioned in ground intelligence); the state of activity and scheduled output of a new aero-engine plant in Austria was received from a refugee mechanic. The information received led to the successful bombing of the first two plants mentioned, the aero-engine plant has, however, still not been attacked because of the delays in getting into production mentioned by the source.

Interrogators in England, North Africa, and Italy worked in close collaboration with the target-assessment groups; the needs of the latter were passed on by means of periodic priority lists which outlined the problems requiring resolution. In important instances, representitives of the target-analysis groups attended the interrogations.

D. Floorspace Studies

Relative "productive" and "non-productive" areas of important plants covered were carefully studied in an effort to determine whether all of a firm was located at a given plant site or whether other, as yet unknown, plants were part of the complex. Study of the first cover of the Wiener Neustadter Flugzeugwerke plant suggested that only some 60 to 65 percent of the entire firm was located at the two plants in Wiener Neustadt. Intelligence and, later, P/W reports helped locate the other plants of this firm. Floorspace ratios of British firms were largely used in determining the relative output of the German plants, and consideration was given to the relative areas occupied by machine and press shops, component erection and final assembly as well as to overall considerations.

In making these studies it was assumed that the German labor policy was integrated throughout the economy, that all plants worked the same number of manhours per month. In addition it was assumed that the plants studied had all reached the same relative degree of full production. This proved erroneous, and led to some fallacious conclusions. In general, floorspace estimates must be used with considerable caution. The attached notes are based on American experience and include some applications to German airframe and engine plants.

E. Nameplates

The importance of captured equipment[1] in furnishing production figures and the names of the manufacturers of components is too well known to be discussed at any length here. It must be emphasized that quite often only the firm name is given for a particular component, making it impossible to determine which plant of a complex is producing a given wing or fuselage, etc. The German practice has suggested that the parent plant engages in fuselage erection and usually final assembly; wings are often made at other plants of the complex or by subcontractors; control surfaces, etc., are, to an even larger degree, made outside the main works.

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[1] This term includes name plates, log books, compass cards, casting markings, trade marks, inspection stamps, etc.

F. Target Analysis

The need to integrate these various sources of information is also obvious. No one of them contains the complete answer on plant activity, and all pertinent information must be coordinated in a single agency. Thus, detailed knowledge of the layout of a plant becomes increasingly important as the site area increases -- i. e. precise knowledge is not too important for bombing a small compact plant the area of which lies within the expected bomb scatter. This knowledge is, however, necessary for a sound appraisal of the damage done to any installation. Aerial cover is useless once a plant is bombed successfully and is then not repaired. Alone, it cannot answer the question of where to look next. The random questioning of Ps/W will lead to useful results only upon rare occasions; this invaluable source must be tied into the needs of a target group.

VI. SOME POSSIBLE IMPLICATIONS FOR JAPAN

There are several points in the European experience which might have extrapolative value for a program of strategic bombardment against Japan:

A. Concentration of Attack in Time and on One Particular Target System

The program against the German aircraft industry got off to a relatively slow start, there being only a total of seven USAAF attacks during the period 28 July -- 31 December. As a result, "systematic" effects were probably kept at a minimum as undamaged plants were probably worked overtime. The concentrated raids of February to April 1944 removed all flexibility from the system.

The attacks on oil targets well illustrate this need for concentration. Neither the August attacks on the Ploesti refineries nor the attacks on the Gelsenkirshen and Wesseling synthetic plants affected the Axis oil position. Excess refining capacity reduced the loss from the former raid to slightly more than the loss of stocks in process; the raids on the latter two plants did little physical damage. Once force and bases were available, however, the recent overwhelming attacks on this industry produced sharply different results. In the first half of 1944 there have been 81 attacks on 52 installations (excluding storage facilities) and of these, half (40 attacks on 29 plants) occurred in the month of June. As a result it is estimated that output has declined by 40 percent between April and June.

B. The Necessity for Large Areas of Physical Damage

It has been pointed out that when plants making a single component for an aircraft were attacked, there was a possibility for cross-flow of parts and subassemblies with other plants if the damage was not widespread. It is probable that far less will be known of the precise function of any building in a Japanese plant, and that at least the same relative degree of damage (25 to 40 percent of the total plant), as was done to Erla at Leipzig/Heiterblick and Messerschmitt at Regensburg, etc., must be done before a plant can be considered to be knocked out.

C. Maintaining Reduced Output

It is believed that the output of German SEF will not be kept below 400 per month over any significant period. Production in June is estimated to be about that level, an all-time low, but recovery and dispersal of damaged plants, increased output of small subcontractors, and undamaged facilities suggest that this figure cannot be sustained. Output may be kept at 600 per month, which is two-thirds of the peak of 900 reached in July 1943, and is 40 percent of the estimated scheduled output of 1500 for June 1944. The flexibility with which bombers can be converted into fighters suggests that output of TEF will not be maintained far below

150 to 175 per month although output had at one time been brought below 100 per month.

It will, of course, be far more difficult to police the Japanese industry. If dispersal of severely damaged facilities is made, there will be little or no ground intelligence within a significantly brief period to permit a satisfactory policing program. It is unlikely that (1) airframe output would be brought below one-third of pre-raid levels or (2) that it could be maintained at less than 50 percent of this level.

D. Aero-engines vs. Airframes

As an alternative it might be well to consider aero-engines as opposed to airframes. Early in this report it was stated that airframes were chosen over aero-engines because of the limited striking force available, the geographic limitations, the cushion resulting from stocks, etc. Lately, however, there has been an increasing number of attacks directed against aero-engine plants, some of which have been picked as targets of secondary importance to oil, airframe, and ball-bearing plants, but many of which are a logical step in the policing of the aircraft industry.

1. Advantages of Aero-Engines

It is quite probable, however, that, given other operational and geographic factors, aero-engines would make a more attractive target than did airframes. Points in favor of this system include:

a. A Much Higher Concentration of Machine Tools

About 35 percent of an aero-engine plant is composed of machine-tool working-area as compared to five to eight percent for an airframe plant (See Appendix A). Sixteen attacks on 12 airframe plants in Germany are estimated to have destroyed or seriously damaged nearly 2,000 machine tools, and comparable damage to aero-engine plants would have increased this type of destruction four-fold. It is believed that hard-pressed Japanese machine tool industry may well be swamped under the burden of large-scale damage to this industry.

b. Qualitative Superiority of Tools

In addition to this concentration of machine tools, the close tolerences and high quality of work demanded by the modern aero-engine require that the best machine tools be used in this industry. The airframe industry's demands are not so exacting, excepting possibly the spar millers, and the problems of replacement or emergency subcontracting are accordingly less.

c. Concentration of Processes

American plants have a large overall percentage of subcontracting of aero-engine components but there is, apparently, a tendency to keep the manufacture of the more difficult parts under the aegis of the parent company. Light metal castings are subject to rigorous inspection and a very high percentage of their necessary machining is done by the parent plant. The subcontracting is principally of small steel parts which bulk large in terms of manhours. Thus, heavy damage to an aero-engine plant would probably knock out its entire output even though a high percentage of its output is done by outside firms.

d. Aerial Recognition

Airframe factories adjacent to landing fields present no special problem of recognition but component plants, whether airframe or aero-engine, and most light engineering plants in general resemble each other so that without prior knowledge it is generally impossible to distinguish one from another. Larger engine plants, engaged in assembly, will have test beds nearby which should be a strong clue as to their identity. In Germany two types, hanger and dynomometer, are used. The former are easily recognized by the air intake and exhaust towers used in each test cell; the latter are sometimes more difficult to spot.

2. Disadvantages of Aero-Engines

Disadvantages to an attack on the engine industry are:

a. The Probable Necessity of Attacking All Producers of Operational Aero-engines

If a single type of aircraft has top-ranking target priority it will not be sufficient to attack only the plants producing the engines used in that particular plane. The Japanese engines are sufficiently similar in overall dimentions to enable them to make a fairly ready readjustment of engine mounts, accessories, etc., from one model to another. This procedure would, of course, deny engines to planes engaging a lower priority-rating, but would keep the high-priority planes in the air. The interchangeability of liquid in-line and radial aircooled engines on such standard German models as the Ju 88 and the FW 190 strongly suggests the Japanese, too, would make this shift.

b. Cushion and Lag Effects

Damage to aero-engines can be partially offset by reducing the flow of engines to lower-priority users, by decreasing the number of spare engines and even by recalling some spares from the field. These reduce the immediate impact in aircraft production.

c. Possible Dispersal within a Complex

It was mentioned above that the engine manufacturers would probably keep the fabrication of the more difficult components under their own surveillance. This does not mean necessarily that a large manufacturer -- Mitsuibishi, for example -- would have to keep the manufacture of these components in one plant. Chevrolet, which produces about 70 percent of its own requirements, for example, has three plants around Tonowanda, N.Y. These three plants, however, account for less than two-thirds of the entire complex as there are also plants in Buffalo, Detroit, Flint, Saginaw, etc. In other words, no one plant accounts for over 25 percent of the entire complex -- yet all parts would presumably bear the name "Chevrolet, Tonowanda."

The best available check against this possibility is correlation of all available evidence -- nameplate and ground intelligence both correlated with study of aerial photographs.

E. The Effects of Heavy Damage to Aero-engine Plants

It has been a rather well disseminated tenet that the law of diminishing returns sets in once structural damage exceeds one-third of the productive area. This conclusion is doubtless correct for German plants, but may not hold true for certain Japanese industries, such as the aero-engine industry. For an isolated incident of course, damage over this classic limit might not result in a proportional loss in output; attacks on the system as a whole, however, might well obtain more than proportional results by "heavy" damage, resulting in half or three-fourths of a plant's being destroyed.

The appendix following this section suggests that aero-engine plants devote 25 to 50 percent (about 35 percent on the average) of their total floorspace to machining operations. Thus, a plant of one million square feet, producing 350 engines per month, would devote about 350,000 square feet to machine tool operations and would utilize some 2000 machine tools.

If 50 percent of the machine-shop area of four such plants were destroyed, the resulting loss of 4000 machine tools might well overtax the replacement facilities of the entire economy. "Heavy" damage would, moreover, insure the complete stoppage of whole departments. The plan attached to the appendix is one of a modern British plant; even cursory study shows that there is a considerable concentration of various processes. This applies not only to the simple distinctioning between steel and non-ferrous machining, but also to the isolating of gears from crankshafts, of cylinder block from supercharger casings. When it is recalled that an engine plant tends to retain the more difficult machining processes and only farms out those relatively simple operations, the importance of complete destruction of any one complete stage becomes apparent.

The identification of building functions in Japanese plants will probably be an extremely difficult one. Heavy damage will be necessary to insure a minimum "cross flow" of components from other undamaged departments at plants making comparable components. Thus, referring once more to the plan given in the appendix, it is apparent that, if buildings C-1, C-2, and B-2 were completely destroyed, the remainder of the plant could not maintain some type of output and even receive the necessary components from other plants. The more the Japanese rely upon general-purpose machine tools, the easier such "cross flow" help could be, and the need for damage exceeding the classic limit becomes the more necessary.

F. The Effect in Time

Successful attack on an airframe plant will normally be felt on first line strength somewhere between two weeks (for final assembly) and two to three months for the deepest processes. Aero-engines would lag by about the same minimum amount for assembled engines but the deeper processes range from three months up to six months for certain rough castings and forgings. The bulk of the machining processes is done one to two months ahead of assembly -- i.e., about three months before the effect would be felt in first-line strength. The recall of spares and the privation of low-priority users would ofcourse add to this period.

This lag should be more than offset by a considerably longer recuperation time. As mentioned earlier, it is believed that a severly damaged airframe plant can be brought back to full scale production by eight to nine months time; there is little or no empiric evidence to check the recovery for engine plants, but it is highly likely that this period would be at least one year and probably more. Destruction or severe damage to 5000 machine tools alone would ensure this period of recovery. Assuming this degree of damage can be done to the Japanese aero-engine industry, the results on finished output may be expected to be about as follows:

Months after attack	Supply- (percent)
1	100
2	90
3	75
4	50
5	20
6	25
7	30
8	35
9	40
10	50
11	70
12	90
	± 55 percent

In addition, serviceability of aircraft in squadrons will be considerably decreased during this period due to recall of and lack of new spare parts.

5. Other components. Random RAF attacks on two important components -- landing gear (for SEF) and piston rings --

reduced the supply of these about 50 percent. In neither case has there been any evidence to date of a shortage affecting operative strength or supplies to new aircraft, as these effects have to a large degree been made redundant by the attacks on the airframe industry itself. Even the severe and persistant attacks on bearings have not affected aircraft output to date, although military equipment of some type or other might be feeling the pinch within the near future.

Considerable difficulty surrounds a successful attack on most minor components. Propellors might seem to be attractive target systems but a vice-president of DeHaviland pointed out that ordinary props without pitch control would have been used by the British, if necessary.

Moreover, there may be considerable difficulty in recognizing which part of which plant makes props, spark plugs, switches, etc. The name of a firm or a component is no guarantee of its target identification.

APPENDIX "A"

MACHINE-TOOL REQUIREMENTS IN AIRCRAFT AND AEROENGINE PLANTS

The data presented in the following tables, although sketchy, may be of use in estimating Japanese requirements. In Table 1, under the column "machine tools" are included bending, boring, broaching, drills, grinders, millers, lathes, planers, and auto-screw machines for airframe plants. In addition, one of the engine plants includes hones presses, punches, and shapers. Shears, saws, crumpers, etc., are excluded from either list. It will be noted that the twin-engined fighter plant (German) has far fewer tools than American plants. This plant has, in all, about double the number of tools shown, the remainder being located in the jig and carpenter shop and not included. The list may be incomplete (as is suggested by the atypical percentage distribution), and the term "metal working shop" may include much more than simply the machine shop for this plant. The area per machine tool is seemingly high for the first engine plant shown but the number excludes all honing, presses, lappers, etc., the numbers of which are not known.

In general a figure of 100 sq. ft. per machine tool is a not unreasonable first approximation for either airframe or engine plants.

These figures suggest that aero-engine plants have about five to six times as much floorspace devoted to machine shop work as do airframe plants. This is, of course, reflected in the number of machine tools per plant, data for which at several

U.S. plants are presented in Table 2. For example, one U.S. airframe plant of 1,100,000 sq.ft. has 670 machine tools while an aero-engine plant of 1,300,000 sq.ft. has 3,348 -- i.e., although only slightly larger, it has five times as many machine tools.

Nearly 40 per cent of the major machine tools in an airframe plant are drilling machines. Grinding machines make up something like one-fifth of the total while lathes and millers are both slightly below 15 per cent of the total. Grinders and lathes have far more relative importance in engine plants, being slightly less than 30 and 35 per cent of the total respectively; drills account for slightly less than one-fifth of the total and millers account for 10 per cent. Data on gear grinders are quite scanty: they make up 11 per cent of the total at the one plant for which figures are available. The available figures are given in the following table; again it will be noticed that presses, etc., are excluded from totals for airframe plants:

TABLE 1. MACHINE SHOP AREA OF SELECTED AIRCRAFT PLANTS

Plant producing	Maximum output per month	Machine shop area (1000 sq. ft.)	Percent of total plant area	Percent of output sub-contracted	No. of major machine tools	Sq. ft. of area per machine tool
4-eng. bomber (US)	100	98	6	±5-10%	1,102	89
4-eng. bomber (British)	90±	120[a]	9[a]	slight (?)	--	--
2-eng. bomber (German)	120	47[b]	7	slight (?)	114[b]	410
SEF (USA)	250 (±250 trainers)	60	6	5-10%	609	100
Dive bomber (USN)	300	68	5 6%	±50%	1,007[c]	68
Radial engine (US)	900	840	26	35+%	5,051	165
" " "	3,000[d]	570	38	30% (for the complex)	6,194[e]	--
" " "	2,800	343	26		3,348	102
In line eng. (UK)[f]		645	32	slight	--	--
Radial eng. (UK)		340	52[g] ±35%		--	--

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a. Including heat treatment
b. Excludes jig shop
c. Includes tool room, etc.
d. Two plants of complex
e. Entire complex of 11 plants
f. Excludes foundry
g. Includes sub-assembly, etc.

TABLE 2A. NUMBER OF MACHINE TOOLS AND PRESSES AT SEVERAL US PLANTS

Plant	Bending	Broaching	Boring	Drilling	Grinding	Lathes	Millers	Planers	Presses	Punches	Shapers	Shearers	Miscel. machine tools	Total
4-eng. bombers	30	1	14	458	291	169	133	2	(89	39	11	103)		1098
2-eng. bombers														
2-eng. bombers[a] (German)				37	30	68	39	6	(55	5		38)	27	207
Dive														
Dive bombers	56	1	14	406	124	172	211	2	(121	34	36	64)	45	1031
Torpedo bombers	1		5	360	116	55	57	1	(65		18	30)	±50	645
SEF (USA)	21	14	1	162	112	145	152	2	(64	14	14	37)		609
SEF "	25	3	10	448	132	116	114	2	(88	11	26	35)	429	1297
SEF (USN)	33	1	7	196	149	77	83	5	(57	—	21	28)	±85	636
SEF (USA)				111	68	47	42		(10)				35	303
Radial eng.	5	30	200	1180	1240	1454	660	3	124	3	16	6	1286	6207
Radial eng.		12	120	601	987	903	305	2	116		99		203	3348
Radial eng.	?	?	328	1004	1146	947	488	?	?	?	?	?	1138+[b]	5051+

a. Excluding those in jig and carpenter shop.

b. Including 512 gear grinders.

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TABLE 2B. PERCENT OF MACHINE TOOLS AND PRESSES IN SEVERAL US PLANTS

Plant	Bending	Broaching	Boring	Drilling	Grinding	Lathes	Millers	Planers	Presses	Punches	Shapers	Shearers	Miscel. machine tools	Total
4-eng. bombers	3	-	1	42	27	15	12	-						100[a]
2-eng. bombers				18	15	33	19	3					12	100
Dive bombers	5	-	1	39	12	17	21	-					4	100
Torpedo bombers	-	-	1	56	18	9	9	-					7	100
SEF (USA)	3	2	-	27	18	24	25	-						100
SEF (USA)	2	-	1	35	10	9	8	-					34	100
SEF (USN)	5	-	1	31	23	12	13	1					13	100
SEF (USN)				37	22	15	14						11	100
Radial eng.	-	-	3	19	20	24	11	-	2	-	-	-	21	100
Radial eng.	-	-	4	18	29	27	9	-	3	-	3	-	6	100
Radial eng.	-	-	6	20	23	19	10	-	-	-	-	-	23	100

a. The percents in this column are not additive due to rounding.

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